

The University of Chicago

THE GRANITE-PORPHYRIES
OF GREAT BEAR LAKE, NORTHWEST
TERRITORIES, CANADA

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
PHYSICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY AND
PALEONTOLOGY

1934

By
CHRISTOPHER RILEY

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CHRISTOPHER RILEY
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ABSTRACT

A granite-porphyry mass, one of a number of porphyries with complex relationships occurring in the pre-Cambrian of Great Bear Lake, is defined. A description is given of the various phases of the formation, its contact phenomena, its apophyses, its form and possible origin, and post-intrusive alterations of a pneumatolytic character. Associated formations are briefly described, and some of the interesting physical features of the region discussed.

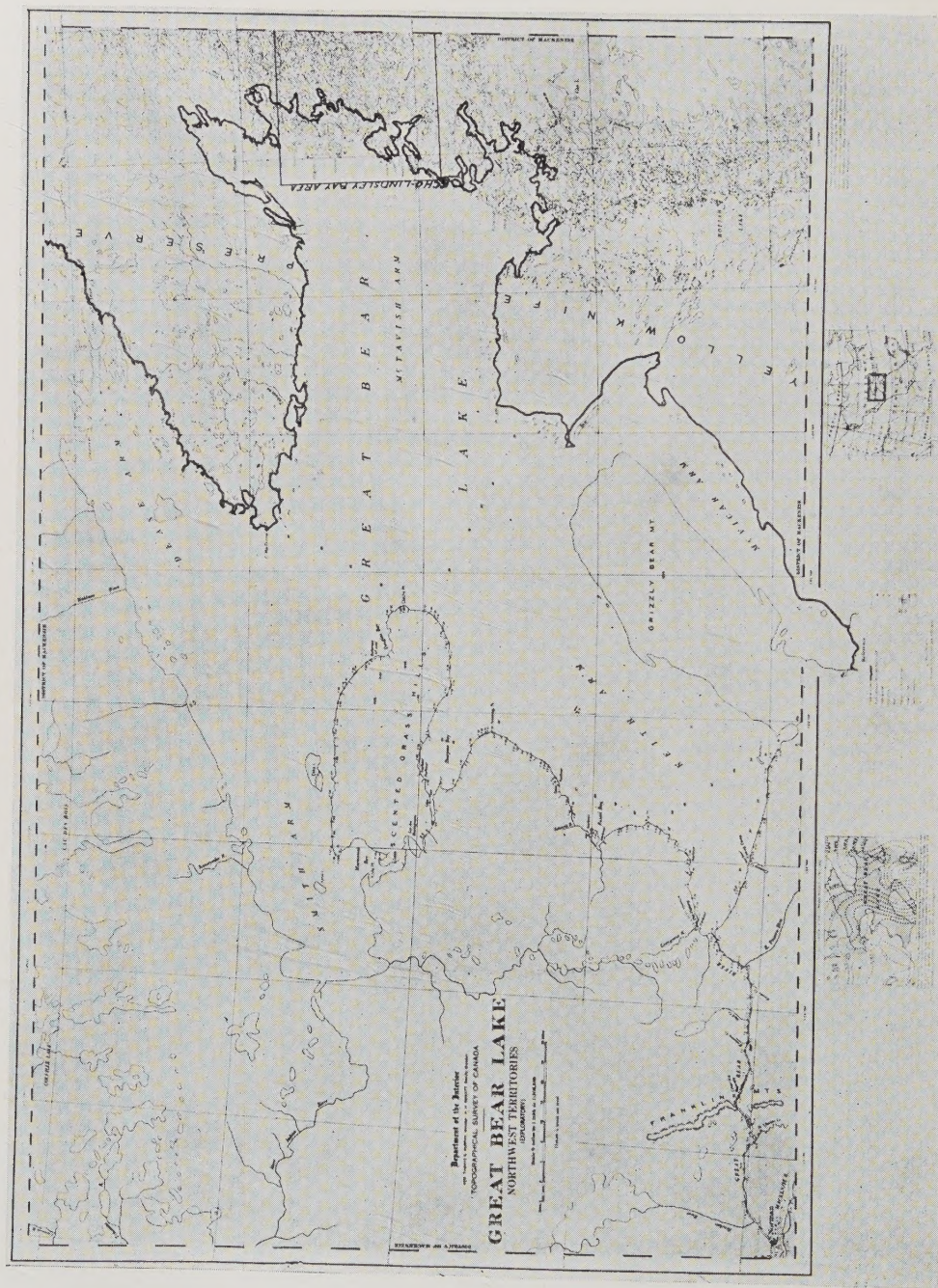
PHYSICAL FEATURES

Great Bear Lake lies on the Arctic Circle in the Northwest Territories of Canada. It is one of the great lakes of North America, ranking next in size to the Great Lakes. It is a large lake, being formed of five large arms, the largest of which is the western arm, the McTavish Arm. On the eastern shore of the lake occur the formations to be described in this paper. This will be called the Lindsley Bay area.

The rocks of the Lindsley Bay area are pre-Cambrian in age and contrast sharply with those of the rest of the lake. The old rock is of a form of rugged hills; while the late rocks form a rolling outline of the lake shore, as is clear from the complex shores and numerous offshore islands. Compared with the smooth shores of the lake, the immediate type of topographical expression appears on the peninsula north of McTavish Arm, where the rocks are probably late pre-Cambrian and are less deformed than those on the eastern end of the arm.

Raised beaches are commonly seen in the pre-Cambrian area. Most of them are small; but one near Hornby Bay at the north end of McTavish Arm has a length of 9 miles, a width of $\frac{1}{4}$ mile, and a top elevation of 500 feet above the present high-water level.¹ Others

¹ D. F. Kidd, *Can. Geol. Surv., Summary Rept.*, Part C. (1931), p. 54.



may be found as far as 10 miles inland and 200-300 feet above the lake level. Isolated as they are from other indications of the former presence of the lake, and surrounded by forests, they present a striking appearance. So far as the writer is aware, no work has been done on the determination of the former extent of the lake; and, in fact, only one other short study has been made of the higher levels of Lake Athabasca and Great Slave Lake, the two other large lakes of the MacKenzie River basin.²



FIG. 2.—Looking west from hills at Smat over volcanics and sediments. Hill in right background is about 1,000 feet above the lake. Small frost-heaved boulder in granite porphyry in foreground.

Heaved blocks, probably peculiar to such latitudes, form an interesting feature of the Lindsley Bay district. In areas of granite and dense porphyries, the frost lifts masses straight out of the solid rock. Apparently the heaving action is begun by water freezing in small joint and sheeting planes. Small, broken rock fragments wedge the block up, and the process continues from year to year. The largest block seen was some 12 feet high and 40×30 feet in horizontal dimensions. The blocks are not numerous, probably because of the rarity of the exact conditions permitting their formation. One of these is shown in Figure 2.

Pseudo-glaciers³ provide another interesting feature of the dis-

² A. E. Cameron, "Recent Glacial Lake in the MacKenzie River Basin, N.W.T., Canada." *Jour. Geol.*, Vol. XXX (1922), p. 337.

³ In an earlier paper (*Can. Min. Jour.*, April, 1933), I have referred to these as "temporary glaciers," but on the suggestion of Dr. J Harlan Bretz, of the University of Chicago, have here used the more appropriate term "pseudo-glaciers."

trict. Some streams, where the gradient is fairly steep, freeze and overflow, and continue the process until ice masses, up to 50 feet thick, 300 feet wide, and 1 mile long, are formed. They are melted

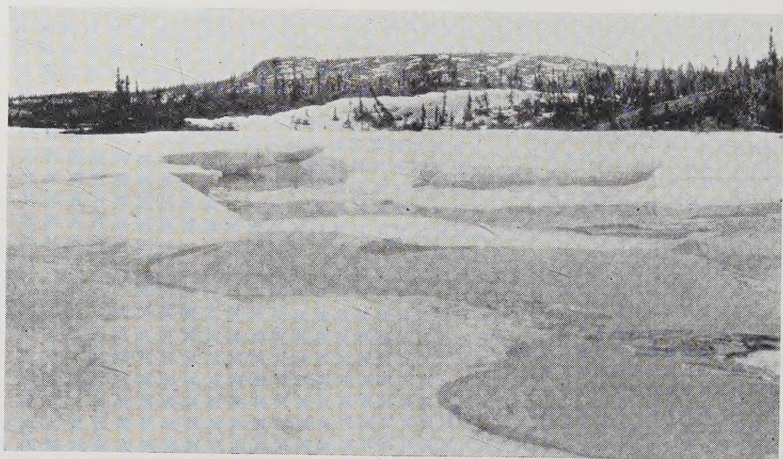


FIG. 3.—Pseudo-glacier in June



FIG. 4.—Course of a pseudo-glacier

by the first of August, leaving rock surfaces clear of all vegetation. The ice movement is very slight, as the striation from the Pleistocene glaciation may be found in the courses of these pseudo-glaciers. Figures 3 and 4 show the glaciers and their courses.

As in other parts of the pre-Cambrian shield, lakes are numerous.

Here they average one or two to the square mile, and compose about one-third of the surface. The mantle of drift is light and is confined mainly to the valleys. The forests are thin and consist predominantly of spruce, with some white birch and poplars. There is but little undergrowth, and bush travel is not difficult.

GEOLOGY

The first geological work on Great Bear Lake was done by Bell,⁴ who, in 1899, made a reconnaissance trip around the lake and described the rocks briefly. Nothing further was done until the mineral discoveries of 1930 began to take technical men into the field. Since then a number of papers have appeared, of which those giving tables of formations are listed below.⁵ These studies deal chiefly with a district about 15 miles south of Lindsley Bay, around Echo Bay, where the important mineral deposits occur.

The rocks of the Lindsley Bay area and vicinity may be grouped in a general way as a series of pre-Cambrian volcanics, sediments, minor intrusives, and large bodies of granite. Of the first three types, porphyries form by far the greater part, and of these there are many varieties. Their separation forms one of the harder geological problems of the field, as their relationships are complex. This is due largely to a similarity of appearance, to the difficulty in outlining their boundaries, and to the obscurity of their origin. Since to map and describe all of them would be a work of considerable magnitude, this study confines itself to one only, called here the "Lindsley Bay granite-porphyry." The formations associated with it will be described briefly. The table of formations for the Lindsley Bay area as given by Kidd⁶ is as follows:

Basic dikes and sills; large quartz veins
Granite and other acid plutonic rocks
Sedimentary and volcanic complex

⁴ J. M. Bell, *Can. Geol. Surv. Ann. Rept.*, Vol. XII (1899), Part C., p. 26.

⁵ C. R. Knight, "Pitchblende at Great Bear Lake," *Can. Min. Jour.*, Vol. LI, No. 41 (1930); J. A. Reid, "The Minerals of Great Bear Lake," *Can. Min. Jour.*, Vol. LIII, No. 2 (1932); D. F. Kidd, *Can. Geol. Surv., Summary Rept.*, Part C. (1932, 1933); C. Riley, "Some Mineral Relationships in the Great Bear Lake Area," *Can. Min. Jour.*, Vol. LIV, No. 4 (1933); H. S. Robinson, "Notes on the Echo Bay District, Great Bear Lake," *Can. Inst. Min. Met. Monthly Bull.* (October, 1933), p. 614.

⁶ *Op. cit.*, p. 4C.

The following grouping is herewith given, thus adding the granite-porphyry to the others:

- Basic dikes and sills
(Intrusive contact)
- Granite
(Intrusive contact)
- Lindsley Bay granite-porphyry and apophyses
(Intrusive contact)
- Volcanics and sediments

In an earlier paper⁷ the writer presented a similar table except that a rhyolite-porphyry was added. This he has since recognized as one of the apophyses of the granite-porphyry.

VOLCANICS AND SEDIMENTS

The volcanics and sediments of the Lindsley Bay area comprise a number of formations of which three main types were observed in association with the Lindsley Bay granite-porphyry. These are sediments, quartz-porphyries, and andesite-porphyries.

Andesite-porphyries.—The andesite-porphyries occur in contact with the granite-porphyry from a point 1 mile south of Smat to the northeastern end of Vance Peninsula. They also occupy a similar position across the peninsula south of Domex Bay, on Cornwall Island, and on Boadway Island. Andesitic rocks of somewhat different appearance occur on Stevens and Achook Islands.

The andesites are dense, massive, and resistant rocks, generally dark gray, but in some cases red-brown in color. Feldspar phenocrysts are prominent in hand specimens with a few quartz phenocrysts occurring in the dark-gray types. Thin sections show phenocrysts of quartz, feldspar, biotite, and hornblende in a felty ground-mass consisting of microlites of plagioclase feldspar. The quartz phenocrysts are few and commonly show partial resorption. The feldspars are generally altered beyond recognition; but where determination is possible, they are andesine, about $\text{Ab}_{65}\text{An}_{35}$. Fresh biotite is rare, though all slides show its alteration products. Hornblende occurs in a few specimens only. Zircon and apatite are accessory. The composition of the rock is that of andesite and quartz-andesite.

⁷ "Some Mineral Relationships in the Great Bear Lake Area," *op. cit.*, p. 25.

Quartz-porphyrries.—Quartz-porphyrries outcrop in many places from Smat northward to Western Channel, and also in a belt of volcanics and sediments extending southeastward from Gilleran Lake, not shown on the map. They form contact with the granite-porphyrries in one locality only, and no attempt is made here fully to define their boundaries. Little field evidence of the extrusive or intrusive character was secured; but microscopic evidence suggesting the former is the presence of shattered phenocrysts, flow textures, spherulites, inclusions of other rock types, and patches of devitrified glass. While such phenomena are occasionally found in dike rocks,⁸ the widespread occurrence of these quartz-porphyrries and the fact that hypabyssal forms are not plainly apparent in the field tend to support the microscopic evidence.

There are several varieties of this rock. A brownish-gray type with numerous, small phenocrysts of quartz and fewer phenocrysts of feldspar occurs 2 miles south of Smat on the lake shore, on the southwestern part of Rocher Rouge Island, in several localities in the belt southeast of Gilleran Lake, and interbedded with grits on Cornwall and Stevens Islands. A dark-gray quartz-porphyrries with red phases and carrying numerous rock inclusions outcrops on the northeastern part of Stevens Island, at Survey Post 33, on a reef $\frac{1}{2}$ mile north of Cornwall Island, and on the shore of Achook Island due west of this reef. Red rhyolitic rocks carrying fragments similar to the andesite-porphyrries in composition and appearance occur on the northwestern part of Cornwall Island.

All the varieties of the quartz-porphyrries belong to the granite family. Thin sections generally show phenocrysts of quartz, orthoclase, plagioclase (about $\text{Ab}_{70}\text{An}_{30}$), biotite, hornblende, and accessory apatite and zircon in a cryptocrystalline groundmass which in places consists partly of quartz. Flow textures are strongly developed, and spherulites and devitrified glass occur in some slides.

Sediments.—Sediments occur on the northeastern part of Rocher Rouge Island, the southeastern part of Achook Island, the southwestern part of Cornwall Island, the central part of Stevens Island, and on Watt Cape. In all these localities they are intruded by phases of the granite-porphyrries. Their strike in each place is indicated on

⁸ A. Harker, *Petrology for Students* (6th ed.), pp. 100–112.

the map by the direction of the parallel lines which form their symbol.

Conglomerates, grits, and banded rocks of fine texture are the three main types. The conglomerates are generally brown in color, and are formed mainly of light-colored pebbles and boulders of porphyry, some of which have the same composition and appearance as some of the quartz-porphyries. The pebbles are rounded, but the percentage of soft rocks and the angularity of the particles of the gritty matrix indicates that the wear has not been great. The conglomerates grade into dark-gray, coarse grits, consisting largely of small rock fragments, feldspar crystals, and a few quartz grains. In thin section, these grits show a remarkable resemblance to the quartz-porphyries and appear to have been derived from them. Most of the quartz grains are angular, and a few show embayments. Plagioclase of a composition of oligoclase-andesine may be recognized; and altered biotite and hornblende, together with an odd spherulite fragment, appear. As with the conglomerates, the wear has been slight. The banded rocks are associated with the coarser clastics. They are dark gray in color and of an argillaceous appearance. Some may be determined definitely as water-laid tuffs.

LINDSLEY BAY GRANITE-PORPHYRY

The Lindsley Bay granite-porphyry is a formation lying on the shores of the mainland and on some of the islands of Lindsley Bay. Though its geological relationships were found to be simple enough, several complicating factors prevented their easy determination. In shape it is long and narrow, its longer dimension extending north and south. On its eastern side, the porphyry is intruded by a large body of granite which it closely resembles in many places along the contact. On its western margin it is intrusive chiefly into andesites, to which, for some distance from the contact, it has a similar appearance. Partly because of this and partly because of a peculiar intimacy of the intrusive habit of the granite-porphyry, the contact is difficult to find and the two rocks give the appearance of merging. Furthermore, there are in the district many dikes of granite-porphyry and granophyre which are quite irregular in strike and form, and which also have similar contacts. These dikes appear and disappear in a most confusing manner.

These several characteristics led the writer to suspect, on first acquaintance, that the granite-porphyry and dikes were a formation, probably of migmatitic origin, transitional from the granite to the older volcanics and sediments. Such rocks marginal to granite intrusives are common in the Canadian pre-Cambrian. Under this hypothesis, the dikes could be explained as easily replaceable parts of the older rocks which had been granitized by the action of intrusives lying somewhere below the surface, thus accounting for their irregularities.

This hypothesis, however, did not stand testing fully, and the formation was found to be a large intrusive mass with the texture of a hypabyssal rock, apparently related to a granite massive which lies adjacent to it and which is intrusive into it. There are two or three separate, much smaller masses which have a composition similar to the granite-porphyry and which, with the dikes, may be apophyses of it.

Occurrence.—The Lindsley Bay granite-porphyry extends about 17 miles north of Smat and about 1 mile south, and has, over that distance, an average width of 4 miles, its total area being approximately 70 square miles. On its western side it is intrusive into the volcanics and sediments, mostly into the andesites, and over the greater part of its eastern side is itself intruded by the Lindsley Bay granite mass. The boundaries were not traced in all places; but the gaps are small enough, except in two localities on its eastern side, to eliminate much necessity for speculation regarding their location.

General description.—The granite-porphyry is a resistant rock, commonly occurring in prominent outcrops. Throughout its extent it forms a series of rugged hills, some of which have an altitude of 600 feet above the lake level. As a rule the tops and sides of these hills are free from drift and exposures are good, especially on the peninsula south of Domex Bay, where many square miles are almost entirely bare rock. This locality is shown in Figure 6.

Though the granite-porphyry occurs in a number of textural and color phases, one type is widespread enough to characterize the mass. This is a reddish-brown porphyry with phenocrysts of quartz, feldspar and platy ferromagnesian minerals. The quartz phenocrysts are few and small, giving it more the appearance of a syenite-porphyry than a granite-porphyry. The feldspars are 2–3 mm. in diameter and

GEOLOGICAL MAP

OF THE

LINDSLEY BAY AREA

GREAT BEAR LAKE

N. W. T.

SCALE



LEGEND

- Diabase
- Granite
- Granite Porphyry
- Felsite Phase
- Volcanics and Sediments
- Sediments
- Volcanics
- Quartz Porphyries
- Andesite

SYMBOLS

- Boundary Defined

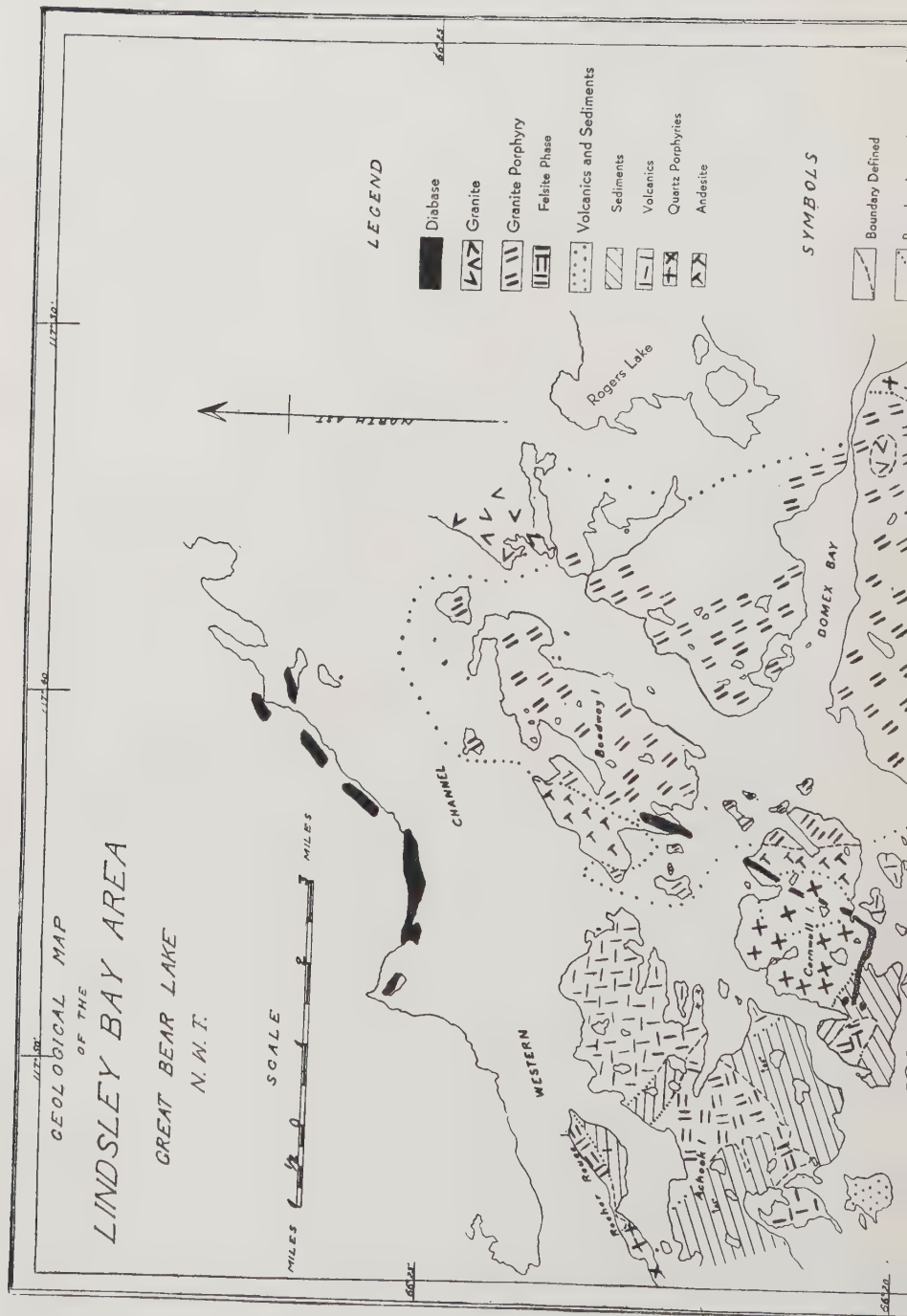




FIG. 5.—Geological map of the Lindsley Bay area

are inconspicuous on fresh surfaces, having about the same color as the groundmass, which is fine-grained, its crystalline character only



FIG. 6. — Granite porphyry exposures on the peninsula south of Domex Bay



FIG. 7.—Typical hillside exposure of the granite-porphyry near Smat, showing jointing.

being discerned by the glint of tiny crystals. The groundmass weathers to brick red, the feldspar phenocrysts to white, and the ferromagnesian minerals weather out, leaving a pitted surface.

The rock has two sets of joints, one of which is strongly developed; the other is much less apparent and intersects the main set at about right angles. Where hillsides parallel the main set of joints and where these are intersected by sheeting planes, a very characteristic stairlike effect is produced, as seen in Figure 7. The distance apart of the vertical joints increases with the coarseness of grain in the rock. Near the western margins of the mass where the grain is fine the spacing is from 3 to 6 inches. This increases in amount up to 3 or 4 feet in the coarser-grained porphyry. The appearance of the jointing in the granite-porphyry and the granite, especially in the stairlike structures on hillsides, is remarkably similar except for the greater coarseness of the jointing in the granite.

The intrusive contact phase seen generally on the western side of the mass is commonly a chocolate-brown rock of flinty appearance. Microscopically, it is a porphyry with a few tiny shattered phenocrysts of

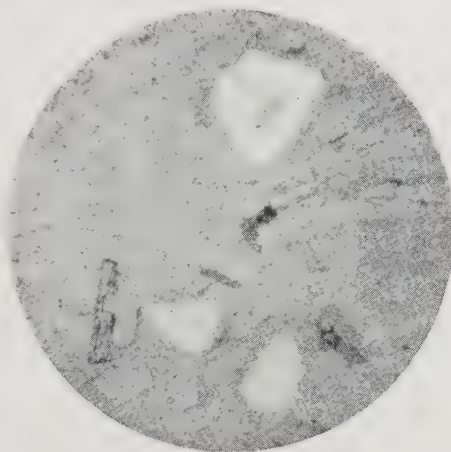


FIG. 8.—Fine-grained granite-porphyry. $\times 36$

quartz, feldspar, and chloritized ferromagnesian minerals in a fluidal groundmass. This flinty rock is confined mainly to the contact, and at a short distance inward the porphyritic character may be distinguished by the unaided eye. Thin sections show phenocrysts of orthoclase, plagioclase ($\text{Ab}_{70}\text{An}_{30}$)—both generally altered, a few crystals of corroded quartz, and a few altered ferromagnesian minerals, among which biotite can be recognized as having once been present. Apatite and zircon are accessory. The groundmass is cryptocrystalline with a few coarser streaks in which quartz and orthoclase may be determined. Fluidal texture is marked. This type is shown in Figure 8.

A medium-textured rock is probably the one most typical of the granite-porphyry. Its megascopic appearance has already been de-

scribed. Microscopically determined the composition is as given in Table I. This rock thus falls into Family 226 (granite family) of the Johannsen classification. The chief difference between this and the

TABLE I

Phenocrysts.....	40%
Plagioclase.....	20%
Orthoclase.....	10%
Quartz.....	5%
Ferromagnesian minerals.....	5%
Groundmass.....	60%
Orthoclase.....	45%
Quartz.....	15%
	100%

fine phase is that the groundmass shows microgranular texture, the individual grains having an average diameter of .01 mm. Figure 9 shows a photomicrograph of this rock.

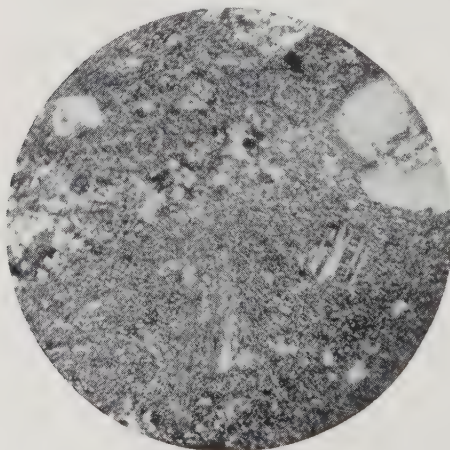


FIG. 9.—Medium-grained granite-porphry. Nicols crossed; $\times 27$.

In many localities the porphyry shows, at a considerable distance from the contact with the older rocks, a comparatively coarse grain which appears more granular than porphyritic. It is light gray in color, spotted with black biotite and augite crystals. Its composition is given in Table II. The groundmass is microgranular in texture with an average grain size of .03 mm. Quartz

and feldspar phenocrysts generally show a secondary enlargement due to a growth of orthoclase or plagioclase around the rims. The feldspars are mostly altered, though they are fresh enough to permit them to be distinguished and to allow the determination of the plagioclase. The biotite is generally unaltered and brown in color, ap-

pearing both as large crystals and in bundles of small ones associated with small green-brown hornblendes and larger magnetites. Augite, clear with a greenish tint, occurs in large crystals, usually

TABLE II

Phenocrysts	50%	
Plagioclase (Ab ₇ An ₃)	20%	
Orthoclase	10%	
Biotite	10%	
Augite	6%	
Quartz	4%	
Groundmass	50%	
Orthoclase	38%	
Quartz	12%	
		100%

partly uralitized. This rock is shown in Figure 10. The difference between this and the finer phases lies in the granularity, the secondary enlargement of the phenocrysts, the presence of augite, the greater freshness of the biotite, and the lack of flow texture. It has a specific gravity of 2.67, which is higher than that of the finer phases (2.63) and close to that (2.66) of the light-gray phase of the intruding granite.

This phase shows clearly the effects of some post-intrusive action which appears to have been instrumental in producing the predomi-

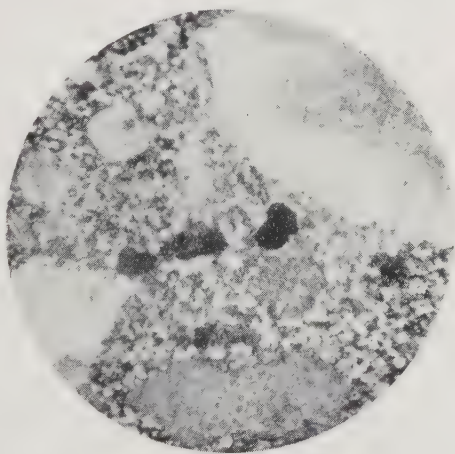


FIG. 10.—Coarse phase of the granite-porphyry. Crossed nicols; $\times 27$.

inating red color of the granite-porphyry. Actually, the light-gray rock forms but a small proportion of the formation, occurring only as small areas in red porphyry of the same texture. Furthermore, the areas of gray porphyry are traversed by numerous red bands. Thin sections from one of these throw some light on the cause of this color

change. This band is about 4 cm. wide, and in its center there is a microscopic veinlet of chloritic material, on either side of which the rock is stained red for about 2 cm. This color fades out as if some solution had penetrated the rock on either side of the veinlet. Within the band, the biotite and augite are chloritized and in part altered to a red hematite dust, as indicated by a halo of this mineral about the altered ferromagnesian. Just outside the red band the biotite and augite are unaltered. This banding suggests that the greater part of the granite-porphyry having this red color has been permeated by oxidizing solutions which have advanced through microscopic and larger fissures and have produced the color, mainly by the alteration of the ferromagnesian minerals and by disseminating hematite dust, a part of the alteration products, throughout the groundmass.

The several textural phases just described are undoubtedly part of the same intrusion. A variant type, however, occurs just north of Failes Lake, different enough in appearance to suggest that it belongs to a slightly different period of intrusion. This is a red-brown felsite, consisting almost entirely of a light-colored groundmass of aphanitic texture in which are scattered altered feldspar phenocrysts of irregular outline. The rock weathers a light brick-red, spotted white where the feldspar phenocrysts kaolinize. Microscopically, the groundmass is seen to consist of quartz in crystals, without sharpness of outline, of a diameter of 1 mm. and another mineral which is probably orthoclase. Two sections, cut from specimens taken close to the granite contact, show a microgranular groundmass consisting of quartz and orthoclase crystals of about .01 mm. in diameter.

Exposures of this felsite were traced northward from Failes Lake for about 3 miles and over a width of $\frac{1}{4}$ mile. The felsite lies adjacent to the granite on its eastern side, and on its western merges into the ordinary granite-porphyry. This merging occurs within a distance of about 1 foot, but careful search revealed no sharp contact. The only evidence suggesting a later age than that of the ordinary granite-porphyry was a section made from that rock taken within 1 foot of the felsite. In this the granite-porphyry showed a micropegmatitic groundmass. Such texture has been found elsewhere only on the granite contacts, and it suggests here that the felsite may be intrusive into the granite-porphyry and that it has caused some recrystallization with the production of this texture.

The granite-porphyry-granite contact.—The contact of the granite-porphyry with the granite is sharp, though its distinctness depends partly on the character of the porphyry in the immediate vicinity, since the coarse type, when metamorphosed, resembles the granite more closely than the fine phase does. The contact is fairly regular and, except in a few places, may be traced without difficulty. No dikes leading out of the granite were found, though there are tiny stringers of it in the felsite porphyry north of Failes Lake. Xenoliths of the granite-porphyry are numerous in the granite up to a distance of 300 yards from the contact.

The thermal metamorphic effects of a granite intrusion on an acid rock are not great, according to Harker,⁹ being limited largely to the recrystallization of the quartz and feldspar with the development of micrographic textures. Hornblende is characteristically replaced by biotite in an aggregate of flakes, making a pseudomorph. In the higher grades of metamorphism, hornblende and biotite are changed to granular augite, accompanied, in the case of the biotite, by much finely divided magnetite. In the case of the Shap granite Harker¹⁰ found microcrystalline textures developed in the ground-mass of a rhyolite for distances up to 600 yards from the contact.

Tarr¹¹ describes similar effects in a rhyolite intruded by a granite in southeastern Missouri. Recrystallization, accompanied by the formation of micrographic textures, occurs at distances varying from 1 foot up to 50 feet from the contact.

The metamorphic effects of the granite intrusion on the Lindsley Bay granite-porphyry are not very different from those described above. In one locality east of Smat light-gray, coarse-grained porphyry of normal type outcrops 75 feet from the granite. At 60 feet it is completely changed in appearance to a light-pink, even-textured rock with the appearance of a fine-grained granite. Thin sections show that the quartz and feldspar phenocrysts have completely disappeared through recrystallization, and that about 50 per cent of the quartz and feldspar is now combined in micrographic texture. Ortho-

⁹ *Metamorphism* (1st ed.), p. 111.

¹⁰ "The Shap Granite and Associated Igneous and Metamorphic Rocks," *Quart. Jour. Geol. Soc.*, Vol. XLVII (1891), p. 304.

¹¹ W. A. Tarr, "Intrusive Relationship of the Granite to the Rhyolite (Porphyry) of Southeastern Missouri," *Geol. Soc. Amer. Bull.* 43 (1932), pp. 965-92.

class forms the greater part of the feldspar. Plagioclase ($\text{Ab}_{70}\text{An}_{30}$) occurs in individual crystals only. Chloritized biotite is present; but the only traces of other ferromagnesian minerals are patches of chlorite, epidote, and magnetite. A few anhedral grains of fluorite occur interstitially. Approaching the contact the grain of the porphyry becomes coarser; and at a distance of 10 feet a few large phenocrysts of orthoclase appear, apparently also developed through recrystallization. The increase in grain size continues up to the

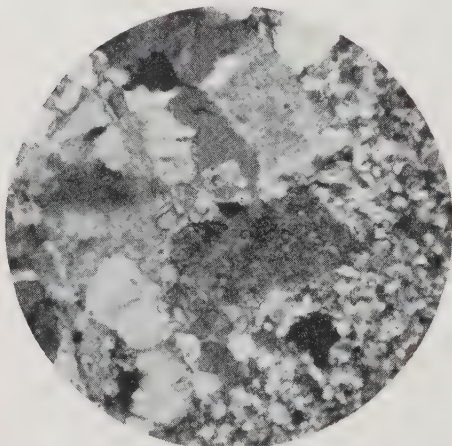


FIG. 11.—Contact of recrystallized fine-grained granite-porphyry and the granite. Nicols crossed; $\times 27$.

granite, which here shows chilling effects and is therefore scarcely distinguishable from the granite-porphyry.

The contacts of the finer phases of the porphyry with the granite are easier to recognize because the porphyry, though recrystallized, remains much finer in grain than the granite. Six thin sections made from specimens taken at or near the contact and from xenoliths show an average diameter of .1 mm. of the recrystallized quartz and feldspar grains.

None show micrographic texture. In some xenoliths hornblende crystals remain unaltered, though in all cases the biotite has been chloritized. Figures 11 and 12 are photomicrographs of the recrystallized fine-grained phase.

The granite-porphyry intrusive contact.—It has already been stated that the contact of the granite-porphyry with the rocks it intrudes is quite obscure and may be traced only with difficulty. This is particularly the case with the andesites near Smat, which appear to have been shattered at the time of the intrusion. Here the contact is most irregular, forming a zone from 5 to 50 feet wide over which the granite-porphyry penetrates the andesite in irregular tongues, even appearing as small, isolated masses within it. Where the intruded

rock has the same color as the granite porphyry, the contacts are especially hard to locate. In some localities, several hundred yards or less from the granite-porphyry, are stringers of a red, felsitic material on either side of which the felsite penetrates the andesite in a very intimate way, so that a zone of 2-4 inches in width is formed of part andesite and part felsite. Figure 13 is a photograph of a polished specimen which illustrates the condition to some degree. Though none was traced back to the porphyry, their composition suggests that they are offshoots from it, possibly of a magma of great mobility injected into narrow shatter zones.

At Watt Cape the granite-porphyry is intrusive into tuffs of varying composition and texture. The contact here varies with the type of rock intruded. Some of the beds were mashed at the time of the intrusion, so that there are many small stringers, short, irregular dikes, and isolated masses of the porphyry in the broken tuffs.

On the other hand, some of the beds are very fine-grained and massive, and there the contact is so distinct and sharp that it is nearly impossible to take a specimen of both types without it breaking along the contact. Where the porphyry is intrusive into beds of coarse, arkosic tuffs, there appears to have been an actual seepage of the magma among the tuff grains, for small, isolated schlieren of the porphyry occur within the tuffs for distances up to 1 foot from the porphyry. There is no actual line of contact as with the andesites, but rather a merging over a distance of 2 or 3 inches, and beyond this there are schlieren for about 1 foot.

Just south of the east end of Domex Bay, where the porphyry intrudes a dark, fine-grained, acid flow, there is also a merging con-

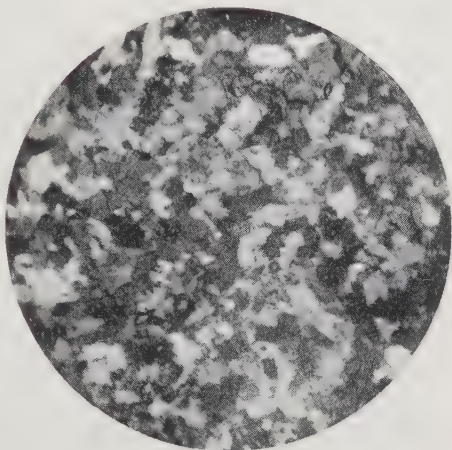


FIG. 12.—Recrystallized fine-grained phase of the granite-porphyry from xenolith. Nicols crossed; $\times 27$.

tact. While the porphyry is fine-grained near the contact, there is a blending of the two over the distance of 1 or 2 feet without the actual penetration by the porphyry as in the case of the coarse tuffs. The appearance given is that of an actual assimilation of the invaded rock over a short distance and its recrystallization as fine-grained porphyry.

The form and origin of the granite porphyry.—There is little evidence by which the precise form of the Lindsley Bay granite-porphyry can be determined. It has an area of about 70 square miles, in places

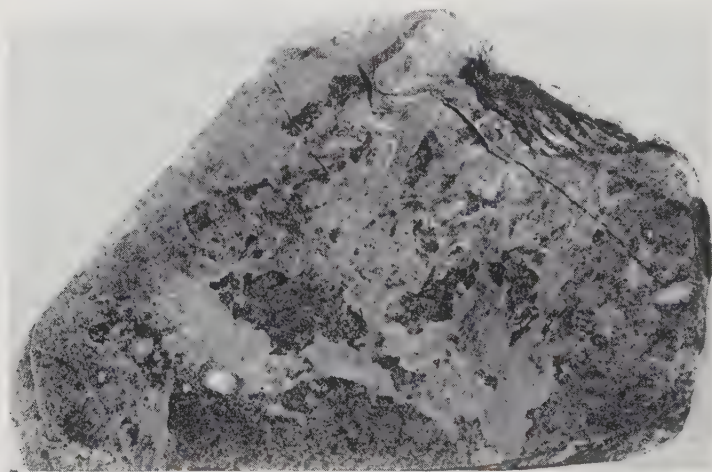


FIG. 13.—Felsite (light-colored) in intimate penetration of andesite. $\times 2$

is over 4 miles wide, and has an exposed thickness of more than 400 feet; yet throughout its extent it has the texture of a hypabyssal rock. It presents the further peculiarity of an intrusive western margin and an intruded eastern margin. In view of the fact that the largest bodies of rock of hypabyssal character described are laccoliths, this mass might be given that name; but it shows none of the structural features of a laccolith and has an area greater than that usually assigned to them. A larger body of basic rock has been given this name by Schwartz, who, speaking of what he calls the "Quizzyhota laccolite," says:

All the dolerites of the Karoo—the sills and dikes of the main portion and the laccolites on the east—belong to one and the same system, they together form

one immense laccolite of the type known as the "Cedar Tree" laccolite The Karoo laccolite is some 700 miles long and at least 200 miles broad.¹²

In this rock, however, the textures are mostly of plutonic character.

A closer parallel to the Lindsley Bay porphyry is the Buttermere and Ennerdale granophyre which has an area of about 40 square miles and which Rastall¹³ concludes was formed under conditions intermediate between plutonic and hypabyssal and may be a laccolith of the "Cedar Tree" type, having been formed by several different intrusions. In the case of the Lindsley Bay mass, however, there is so little evidence that probably the most accurate definition that could at present be made of it would be that it is of batholithic form and of hypabyssal texture.

In origin the porphyry seems to be closely related to the Lindsley Bay granite mass which flanks it on the east. Its main mineralogical difference from the granite is the presence of augite, which is, however, according to Harker,¹⁴ a normal variation, as that mineral occurs more frequently in the granite-porphyrines than in the granites. It seems probable, therefore, that it is an earlier, more shallow manifestation of the intrusion of the granite. It is well known that granite masses show microgranitic, granophyric, felsitic, porphyritic, rhyolitic, and even spherulitic phases on their margins.¹⁵ Cases have also been cited of intrusions of hypabyssal character related to granite and formed in close proximity to it. Lawson¹⁶ describes felsite bodies from the Lake of the Woods district which are concentrically arranged around a granite mass and are probably related to it. Schofield and Hanson¹⁷ find that the Premier quartz-porphyry sills have a similar composition to that of the Coast Range batholith. These sills may represent the first stage of the intrusion of the batholith which was formed during mountain-building movements,

¹² E. H. L. Schwarz, "The Quizzychota Laccolite," *Jour. Geol.*, Vol. XXI (1913), p. 81.

¹³ R. H. Rastall, "The Buttermere and Ennerdale Granophyre," *Quart. Jour. Geol. Soc.*, Vol. LXII (1906), p. 253.

¹⁴ *Petrology for Students* (6th ed.), p. 102.

¹⁵ J. J. H. Teall, *A British Petrography*, pp. 332, 334; also Harker, *Mem. Geol. Surv. Scot.*, Explanation of Sheet 70 (1904), p. 32.

¹⁶ A. Lawson, *Can. Geol. Surv. Ann. Rept.*, Vol. III, Part I (1887-88), p. 145F.

¹⁷ Schofield and Hanson, *Can. Geol. Surv. Mem.* 132 (1922).

as they themselves are involved in the folding. Drysdale¹⁸ found in Ymir, B.C., a granite-porphyry intruded by the younger Nelson granite. The formation of the porphyry probably represented the commencement of the Jurassic revolution of the region during which the Nelson batholith was intruded.

As at Ymir, the granite-porphyry at Lindsley Bay appears to have been the first manifestation of the intrusion of the granite. The conclusion that there is a close relationship is strengthened by the occurrence on the hills just south of Domex Bay of two, long, narrow dikes of granite-porphyry very similar in appearance and composition to the Lindsley Bay porphyry, cutting both that rock and the granite. This suggests that there were later phases of the granite intrusion similar to the preliminary ones.

Structural features.—As in other pre-Cambrian areas, the structure of the Great Bear Lake area is difficult to elucidate, and any evidence which may prove of value in its solution is worthy of note. In the Lindsley Bay area, the present definition of the granite-porphyry is suggestive of the occurrence of a series of great east-west faults. This is indicated by the offsetting of this formation in three localities, in each of which there is a large valley.

One mile south of Smat there is an east-west valley 300–400 feet wide, with hills on either side about the same distance high. The north side of this valley consists of granite-porphyry for a distance of about 1 mile inland from the shore of Great Bear Lake. The south side consists of andesite-porphyry for nearly the same distance before the granite-porphyry appears. This offsetting suggests that the north side has been downfaulted, or that the south side has been thrust eastward.

Four miles northward, on Failes Lake, the granite-porphyry contact with the granite has been offset for about $1\frac{1}{2}$ miles, so that the north shore of the lake is over one-half granite-porphyry and the south shore chiefly granite. Two miles westward in Failes Bay and in the same valley an island composed of older formations lies just north of the granite porphyry of the northeastern part of Vance Peninsula. In this locality, however, there is evidence of another

¹⁸ C. W. Drysdale, *Can. Geol. Surv. Mem.* 94 (1917), p. 33.

fault, probably later, with a northeast strike and accompanied by much shearing and the injection of a large quartz vein.

About 1 mile north of Watt Cape, two small islands lie close together. The more southerly of these consists of the older formations; the other, just to the north, of granite-porphyry. It is significant that these two islands lie 1 mile west of a deep, narrow inlet extending eastward into the eastern shores of Lindsley Bay.

Apophyses of the granite-porphyry.—There are other intrusive masses not connected with the main body of the Lindsley Bay porphyry which are probably closely related to it, as they have a similar composition and are intrusive into the same rocks. One of these, a felsite-porphyry body of irregular shape, occupies about 1 square mile on the central part of Achook Island, where it is intrusive into sediments and volcanics. This rock closely resembles the felsite-porphyry north of Failes Lake, i.e., it is a red felsitic rock with a few phenocrysts of greenish-gray feldspars in a flinty groundmass. Microscopically, it has a cryptocrystalline groundmass in which there are irregular areas of micrographic texture so fine as to be almost submicroscopic. There are a few remnants of altered ferromagnesian minerals, but the feldspar phenocrysts are fresh enough to determine both oligoclase-andesine and orthoclase. Near the southern boundary of the mass, the rock tends to become andesitic, for its groundmass consists mainly of microlites of plagioclase, with the other constituents remaining as before.

The contact of this rock with the sediments is sharp and presents no unusual features. At the south side of the island, however, where it is intrusive into acid volcanics, the contact is of an intricate character, so that the rocks appear to merge. Thin sections show that the intruded rock has been minutely fractured and that the intrusive penetrates all the minute fissures so formed and also constitutes the cementing material of a microscopic breccia, giving a very intimate contact.

A similar type of rock forms the northern half of the eastern part of Rocher Rouge Island and is here intrusive into sediments. There is also a red felsite containing a few large quartz phenocrysts on the

southern part of Cornwall Island, forming a mass about $\frac{1}{2}$ mile square. Throughout its extent it is intrusive into conglomerates and grits, with which it forms sharp contact.

GRANITE-PORPHYRY AND GRANOPHYRE DIKES

Dikes of granitic composition are numerous in the Great Bear Lake pre-Cambrian, particularly east and southeast of the granite-porphyry of Lindsley Bay. In view of the fact that they are similar in composition to that rock, cut about the same formations, and show like contact phenomena, it is probable that they belong to the same intrusive period.

The most notable characteristics of these dikes are their lack of definition and their irregularity along the strike. Most of those examined have a contact difficult to locate because of the blending of the dike rock with the intruded formation, where the effects are similar to those described on the Lindsley Bay granite-porphyry contacts. Where the dike margin is found, it is seen to be chilled, and from this fine-grained edge there is a progressive increase in grain size to the center of the dike. Some of the dikes are differentiated so that the margins are more basic than the center. As noted above, the dikes are irregular. They pinch and swell, disappear and reappear, and in places are offset, which, combined with their blending with the intruded rocks, makes their tracing a slow process. The longest distance over which one of these was traced was $\frac{1}{2}$ mile; but in the district about 2 miles southeast of Domex Bay, where the dikes are numerous, their irregularity is so great that very few can be traced much over 75 yards.

A typical differentiated dike from the area has a width of 16 feet, with margins of dark-gray andesitic rock grading to a center of coarse-grained, light-gray rock with large feldspar phenocrysts. Thin sections from the center show phenocrysts of orthoclase, plagioclase, brown biotite, green-brown hornblende, and apatite in a granophyric groundmass.

Granophyric and granite-porphyry dikes are numerous in the Camsell River district about 40 miles south of Smat. Here they have a general northeasterly trend. In addition there are also small intrusive masses of very irregular form with a granitic composition.

GRANITE

Granite is widely distributed over the pre-Cambrian areas east of McTavish Arm, and there are two main occurrences in the Lindsley Bay area. One of these forms Hogarth, Workman, and a number of smaller islands, and outcrops on the western sides of Vance Peninsula and Achook and Stevens Islands. The other, already referred to as the Lindsley Bay granite, is a mass of about 125 square miles in area, the northwestern part of which is intrusive into the granite-porphyry on its eastern side. There are two or three small bodies of granite intrusive into the porphyry northward from Gilleran Lake to Rogers Lake.

The granite resembles the granite-porphyry in field appearance except for a greater coarseness of texture and of jointing, which is

TABLE III

Quartz.....	27%
Microperthite and orthoclase.....	38%
Oligoclase.....	28%
Dark minerals, mainly biotite.....	7%
	100%

characteristically expressed on cliffs and hillsides, giving the appearance of great stairs. The rise of each step is from 6 to 14 feet, representing the sheeting; and the width of the tread, from 3 to 8 feet. As in the granite-porphyries, the coarseness of the jointing appears to be in direct ratio to the coarseness of grain of the rock.

A few sections of granite both within and without the Lindsley Bay area were examined. All show a similarity of mineralogical composition. Near Smat the granite assumes a number of textural phases and two main color phases—a deep pink and a light gray. The average composition of five slides is given in Table III.

The greater part of the alkali feldspar is microperthite, which occurs in large crystals, somewhat clouded by kaolin and a little sericite. The plagioclase is invariably much more altered, but some is fresh enough to determine as oligoclase. In the pink phase of the granite the plagioclase is red and the alkali feldspar gray. Biotite and hornblende occur, often in bundles of aggregated crystals. These

minerals are rarely fresh in the pink granite, being altered to chlorite and to lesser amounts of magnetite and hematite. In the light-gray granite they are mostly unaltered.

Granite specimens from one locality on Hogarth Island showed, in two slides, the composition given in Table IV. Two slides from

TABLE IV

Quartz.....	34%
Microperthite.....	37%
Oligoclase.....	24%
Biotite.....	5%
	100%

specimens taken a mile south of Echo Bay have the composition shown in Table V. Specimens from both localities show a greater alteration in the plagioclase than in the alkali feldspar, and also the same contrasting colors are found in these minerals as at Smat. Microcline is absent from all slides examined, and apatite is the only accessory noted.

TABLE V

Quartz.....	35%
Microperthite and orthoclase.....	40%
Oligoclase.....	20%
Biotite and hornblende.....	5%
	100%

The greater alteration of the plagioclase than the microperthite and orthoclase is noted in Bell's report¹⁹ of his trip in 1899, where granite from two widely separated districts showed the plagioclase altered to a greater degree than the orthoclase. This alteration appears to have occurred early in the period of rock formation, as indicated in specimens from Hogarth Island, where altered plagioclase crystals are enclosed within unaltered microperthite.

Alteration processes.—A notable feature of both granite and granite-porphry is the coloration effect produced by the alteration of the ferromagnesian minerals. Both rocks show light-gray phases

¹⁹ *Op. cit.*, pp. 31-32.

of limited distribution, which grade into the more common red phases. In the gray rocks the dark minerals are fresh; in the pink and red types they are altered; and hematite particles, part of the alteration products, have been spread through the groundmass of the granite-porphyry and into the altered plagioclase of the granite, producing, in the latter rock, red plagioclase in contrast with the gray alkali feldspars. In some granite slides microfracturing occurs; and the microbreccias thus formed are colored red, as are the margins of fractures in large microperthite crystals, suggesting that this alteration was a post-crystallization process in contrast to the plagioclase alteration which occurred before the full formation of the orthoclase and microperthite.

A condition somewhat analogous to the alteration of the ferromagnesian minerals here has been discussed by Singewald.²⁰ He describes quartz-monzonite-porphyry and monzonite-diorite-porphyry in which all the minerals have been considerably altered, and concludes that the alteration was an end-phase of the intrusive cycle of each porphyry and that the agents causing it were contained in each intruding magma.

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²⁰ Q. D. Singewald, "Alteration as an End Phase of Igneous Intrusion in Sills in Loveland Mountain Park County, Colorado," *Jour. Geol.*, Vol. XL (1932), p. 16.

